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ROOT STUDIES *

THE study of roots is a branch of agricultural research that has remained relatively backward. Admittedly more attention has been paid in recent years to this subject. For example, apart from detailed studies of the root-systems of crop plants a good deal of work has been done on growth promoting substances for the stimulation of root development. There has also been a rather surprising number of papers written about the association of micro-organisms with plant roots but in spite of this attention to a few aspects of the study of roots our knowledge of their mode of action still remains very imperfect.

From the point of view of crop husbandry the interest of roots does not cease with their functions as supports and anchorages for the aerial parts of plants, and as the organs by which water and nutrients are taken in. Roots may be regarded as an underground railway consisting of a system of tubes and lifts by means of which materials move from the soil solution to be delivered in the upper world. There is also the function, exhibited by the roots of many legumes, of supporting nodule bacteria which add something beyond what the plant can obtain unaided from the soil. This, however, is all quasi-mechanical. It appears that the roots have a more dynamic rôle than any of these, and that by means of organic excretions from the plants or possibly simply by their constant dying and renewal they provide the substance of an intense and ever changing microbial life. Rogers (1) has strikingly demonstrated the impermanence of the roots of a plant so substantial as an apple tree. Lochead (2) suggests that studies of "rhizosphere"—as the complex of root and its intimately-associated micro-organisms is termed—will soon reach fullness that will enable much to be revealed to us that is now obscure about the purpose and extent of the rhizosphere actions.

Recent work on the mere extent of roots belonging to one plant has led to the publication of striking figures that would be incredible if one ascribed only a static purpose to roots. The estimates of earlier investigators for the total

* See *Soils and Fertilizers*, **5**, No. 5, 1941, and article on Roots by H. C. Samspson, *Empire Cotton Growing Review*, **16**, No. 3, 1939.

(1) Rogers, W. S.—*J. Pomol.*, **17**, 1939.

(2) Lochead, A. G.—*Canad. Pub. Health J.*, **32**, 1941.

length of roots of a single plant varied from a few hundred yards down to a matter of inches. Thus, Hellriegel estimated the length of the roots of a vigorous barley plant to be 128 feet and that of an oat plant 150 feet. On the other hand, Pavlychenko (3) in 1937 estimated that the root systems of single plants of slender wheat grass, brome grass and crested wheat grass three years old were respectively 10, 65 and 315 miles long, and a single wild oat plant had within 80 days of emergence acquired at least 511 miles of root. Dittmer (4) has added to data of these magnitudes by suggesting that a single plant of rye can grow about three miles of root daily. If one adopts the view that some of the root-material is constantly being discarded and renewed, this is not inconsistent with Pavlychenko's results.

Apart from a few detailed investigations on the root systems of certain tropical crops there is little published information available on this subject and what there is deals only with particular environments. And yet the need for research in the tropics on the root systems of crops is more important than in the temperate regions because the range of environment is so much greater, and environment undoubtedly has a considerable influence on the root development and root system of any particular species or of any cultivated race of a species. For instance, the work which has been done at East Malling in examining the root systems of different races of fruit stocks has shown clearly that these vary both with the stock and with the type of soil on which they are grown. A striking example of the influence of the environment on the root system of a species is the case of the Neem tree, *Azadirachta indica*, which has been introduced into the Gold Coast from India. Under Indian conditions the tree makes a strong tap root which penetrates vertically into the ground for a considerable depth and it shows little tendency to form strong branch roots near the surface. In the Gold Coast, where the tree is now common, the root system consists of a tangled mass of thick surface branch roots extending laterally quite close to what must have at one time been the surface of the ground. In fact, it may be stated that all the common exotic species of trees grown in West Africa develop a shallow root system. This adaptation of the root system to suit a particular environment may explain why it is that trees found useful in one country as shade for a particular plantation crop may prove quite unsuitable or even harmful in a different environment. Another example which may be quoted is that of the sorghum crop. This is considered to be the most drought resistant of cereals and it is presumed therefore that it has a deeper root system than other grain crops although there is considerable difference in this respect between varieties. In West Africa the crop is grown on ridges 3 to 3½ feet wide, and the plants are spaced out 1½ feet apart in the row while on the black cotton soils of India the plants are spaced about 6 inches apart in rows about 14 inches apart. Thus in West Africa each plant has nearly ten times the surface area that the plants have in India. This certainly seems to point to a difference in the root systems of the cultivated races of sorghums in these two regions.

In the case of plantation crops interplanted with shade trees and cover crops it seems essential that knowledge should be obtained on the amount of root competition existing between the shade tree and the crop. This would naturally vary with the type of soil. In heavy soils retentive of moisture and in districts where rainfall is high, such competition may be of actual value, because the roots of the shade tree may assist in draining the soil, thus providing a suitable environment for the roots of the crop. Knowledge of the root systems of plantation crops would also be useful in the laying down of experiments but at present it is generally lacking.

There is little information available on the root systems of arable tropical and sub-tropical crops. In the United States the root systems of several sub-tropical crops which are grown there have been described but it is felt that much more local research is necessary to gain knowledge regarding particular environment and particular races of cultivated crops in our colonies.

There are many ways in which the knowledge of root systems of plants can be turned to profitable account. In Mauritius (5), for example, the root systems of several varieties of sugar cane have been examined in detail with a view to selecting canes for breeding and for cultivating under various local environmental conditions. It was possible by studying the nature of the root systems to indicate what canes were likely to do well in dry localities, in very wet localities, and in localities heavily infested with the root-eating grubs of *Phytalus Smithi*. It was also possible to indicate the degree of cyclone-resistance from the nature of the root-system. Quantitative and qualitative studies on the development of the young sugar-cane root-system were also a great help in elucidating problems connected with the cultivation and manuring of this crop.

Other examples could be quoted of data of practical value which have been obtained as a result of the study of root system. Such studies, however, are not only tedious but often expensive and this is probably one of the reasons why our knowledge of the underground parts of tropical crops lags so far behind that of the aerial ones. With the development of new technique, such as glass chambers and shafts, which allows for observation on the development and reactions of roots, it may be hoped that more attention will, in future, be given to the study of the root systems of crops in our colonies.

(3) Pavlychenko T. K.—*Canad J. Res.*, **15c**, 1937.
(4) Dittmer, H. J.—*Amer. J. Bot.*, **24**, 1937 and *Science*, **88**, 1938.

(5) Evans, H.—*Emp. Jr. of Experimental Agriculture*, **4**, Nos. 15 and 16, 1936.

MOLE-CRICKET PARASITES OF THE GENUS LARRA IN TRINIDAD.

BY

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Introduction.

THE Larrid wasps which parasitise mole-crickets are of exceptional interest because of their habit of paralysing the crickets momentarily, before attaching their eggs, and they are of economic importance because of the serious damage caused by their hosts. Attempts have been made to use some of these wasps in biological control, the latest introduction being that of *Larra americana* from Brazil to Puerto Rico.

In Trinidad, B.W.I. two mole-crickets—*Scapteriscus vicinus* Scud. and *Gryllotalpa hexadactyla* Perty—are very destructive in vegetable gardens and lawns, and though several species of *Larra* have been recorded as parasites of mole-crickets in South America, no wasp of this genus has yet been reported from Trinidad. Within the last five years, however, the following three species have been found here, all near the Imperial College of Tropical Agriculture at St. Augustine.

Larra guiana Cameron—one female, Oct. 23, 1936, R. G. Fennah; one female, Jan. 19, 1941, A. M. Adamson. A third female, probably of this species, was seen by the writer on Mar. 9, 1941, but it eluded capture. A fourth wasp, probably *Larra guiana*, taken by Mr. G. J. Goble on a window at the College on March 17, 1941, escaped before a precise identification was made.

Larra americana (Saussure)—one male, Nov. 20, 1938, L. Lyndon Kerr.

Larra transandina Williams—one female, Nov. 20, 1938, L. Lyndon Kerr.

These wasps must be very rare or localised in Trinidad. None appears to have been seen by several entomologists who have made extensive collections here and who were especially interested in parasitic wasps. It seems certain that they effect no significant control of mole-crickets in Trinidad.

The following notes on the habits and life-history of these wasps are based on observations on one female *Larra guiana* and two generations of wasps reared from it, and on a series of females of *Larra americana* and one generation of their progeny. The wasps of the latter species were imported from Brazil before its occurrence in Trinidad was known. The habits of both wasps and their larvae were found to be very similar to those recorded for several species of *Larra* in South America and elsewhere by Williams (1928) and for *Larra analis* Fabr. by Smith (1935) in Florida. These notes are supplementary to their detailed reports.

The adult wasps were kept in glass jars about 20×12 cms., provided with flowers of *Borreria verticillata*, which Wolcott found to be a favourite food plant of the wasps in Brazil. They fed readily on diluted honey sprinkled several times daily over the flowers. Crickets were offered to the wasps by both methods used by Williams, namely, by allowing them to burrow in soil at the bottom of the wasps' cages, and by confining parasite and cricket together in test-tubes. Parasitised crickets were kept singly in Petri dishes about 10 cm. in diameter, partly filled with moist earth or sand, with grass or lettuce leaves as food, in which conditions they appeared to thrive until killed by the larval wasp. A few crickets died within two or three days after capture, being apparently weakened or injured—it is evident that crickets to be used for experiment should be kept for a few days to eliminate unhealthy specimens.

I am indebted to Dr. F. X. Williams, who was the first to make a thorough study of the habits of Larrid parasites of mole-crickets, for the identification of the species of wasps recorded here; to Dr. G. N. Wolcott, of the Insular Experiment Station, Puerto Rico, from whom I received live females of *Larra americana* from Brazil; and finally to the three collectors in Trinidad already named.

Larra guiana Cameron.

This species was described by Cameron (1912) from a female in the Georgetown Museum, British Guiana. It was found in small numbers in the lowlands of British Guiana, in Berbice County, and in Brazil, near Sao Paulo and at Para, by Williams (1928), who reared one larva on an undetermined genus of mole-cricket. Williams states that *L. guiana* may be synonymous with *L. gastrica* Tasch.

The single female captured at St. Augustine, Trinidad, on Jan. 19, 1941 was kept alive for four days and it parasitised seven adult and two immature *Scapteriscus vicinus*. From the nine eggs, five larvae were reared to maturity and two adult females of the second generation emerged. These females laid five eggs, of which two developed parthenogenetically and produced two adult males, which died before emerging from their cocoons.

One adult *Gryllotalpa hexadactyla* was offered to the first wasp in a test-tube. It had recently parasitised a *Scapteriscus*, and attacked the *Gryllotalpa* after some hesitation, and though the cricket was effectively paralysed, no egg was deposited on it.

The general behaviour of the wasps in attacking the crickets was very similar to that observed in other species of *Larra* by Williams. The first paralysing sting was invariably administered between the first and second pairs of legs. Immediately afterwards the sting was inserted, apparently, from one to several times between the

second and third and again between the first and second legs, the stinging now appearing less precise and varying considerably according to the activity of the cricket, which was promptly subdued in some cases but little affected in others. Having paralysed or attempted to paralyse the limbs, the wasp then inserted the sting in the under-side of the cricket's head. This was invariably done with great precision, after careful searching for the exact spot, in the soft skin near the base of one of the maxillae. Here the sting remained inserted for periods of five to ten seconds. The stinging of the thorax was usually effected by rapid thrusts followed by withdrawal within one to three seconds.

Within about ten seconds after stinging the head of the cricket, unless prevented by renewed struggles of the host, the wasp proceeded to oviposit. All of the eggs were fixed on one side of the thorax immediately in front of the second pair of legs, as in the case of the closely related *Larra americana*.

The effects of the stings on the crickets varied considerably, possibly owing to the unnatural conditions, as the two wasps bred in the laboratory were less successful in paralysing their prey than the wasp caught outside. In most cases, which may probably be regarded as typical, the cricket was sufficiently subdued for egg-laying within about ten seconds. In a few cases the first sting caused almost complete immobility within about five seconds. In one case a wasp fought continuously with a very large adult *Scapteriscus* for a full 30 minutes. The sting appeared to be inserted many times in the thorax, though it was not possible always to distinguish between stinging and searching for the site for the egg. Seven stings were administered in the head, always with great precision, at the base of one of the maxillae. After 28 minutes the struggles of the cricket were momentarily subdued and the wasp attempted to lay. The egg was dislodged and fell in to the soil, but as the cricket again ceased to struggle, a second egg was immediately and successfully laid.

Maxillation was observed on only two occasions, the wasps biting the paralysed crickets on the femur of the forelegs and on the side of the thorax. No feeding on fluids from the bitten parts was noted. On one occasion, during an unusually prolonged struggle, the wasp grasped the base of the forewing of the cricket with its mandibles.

Hatching of the larva was not observed owing to absence of any sufficiently obvious difference between the appearance of the egg and the very young larva, when viewed on the live and active host. In an egg on a cricket which died three days after the egg was laid, the mandibles of the embryo were moving actively on the seventh day (the larva died soon afterwards) and the incubation period of the egg was probably about six days. A conspicuous increase in the size of the young larvae was visible eight days after laying.

The development of the larvae followed the same course as described by Williams for *Larra guiana* and related species. The crickets died ten days after the (presumed) hatching of the larvae (of the second generation), and showed no signs of abnormality in appearance or behaviour until an hour or two before death, when the movements of the legs became less active. (Smith, 1935, found no apparent abnormality in parasitised crickets dissected immediately before the onset of death from parasitism.)

The larvae of the second generation were probably all female. The two larvae of the third generation, which were male, completed their development in two to three days less than those of the second generation.

The pupal cask of agglutinated soil particles was built in all cases as described by Williams. The first part of the cask, suspended in a light framework of silken threads, was a narrow cylinder, 1 to 2 mm. in length, encircling the middle of the larva. The construction of the cask occupied 14 to 30 hours, and was completed on the 18th day after the laying of the egg in the case of larvae of the second generation and on the 14th to 15th day in the third generation.

The length of the pupal stage was not determined, as no casks were opened to observe the change from larva to pupa. The two adult females of the second generation emerged 57 days after the completion of their pupal casks. This prolonged period may have been spent partly in a resting stage, awaiting the advent of the rainy season, as in the case of a larva found by Williams in a cask completed nearly a month previously.

Larra americana (Saussure).

This wasp was studied extensively by Williams (1928) and Wolcott (1938, 1941) and only brief notes are required here.

Before devising a satisfactory technique for shipment of wasps from Brazil to Puerto Rico, Dr. G. N. Wolcott sent me a consignment of adult females collected at Belem, Para, Brazil, in February, 1937. Five of these survived the journey and lived for two to four days, laying 21 eggs, 16 on *Scapteriscus* and 5 on *Gryllotalpa*. Four mature larvae were reared on *Scapteriscus* and three females emerged from them. These lived for 4 to 7 days but no progeny was reared from them.

Judged by observations on a few eggs on dead crickets and cast skins, the incubation period of the egg was probably about 5 days. The parasitised crickets died 17 days after the eggs were laid. The construction of the pupal cask occupied 18 to 24 hours. Three females emerged 46 days later.

Gryllotalpa hexadactyla was accepted for egg-laying apparently as readily as *Scapteriscus vicinus*, the host of the wasps as observed by Williams and Wolcott in Brazil. Unfortunately *Gryllotalpa* did not thrive under the conditions found suitable for *Scapteriscus*, all of them dying a few days after capture. The ability of the wasp larvae to develop on this host was therefore not determined.

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SOME OBSERVATIONS ON THE DAILY MARCH OF PHOTOSYNTHESIS IN THE LEAVES OF SUGAR CANE.

BY

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A certain amount of work has been done in the last two decades on the march of apparent assimilation throughout the day in a few tropical crops, and it has been shown for coconut (McLean 1920), coffee (Nutman 1937), and cacao (Murray 1940), that the photosynthesis rate shows a maximum in the morning and afternoon, with a minimum during the midday period of intense insolation.

McLean, in a preliminary experiment to his work on coconut, found that the sugar cane showed a slight fall in apparent assimilation rate around midday. (This work of McLean's has been criticised on the ground that the concentration of carbon dioxide in the leaf chamber fell to a very low level during periods of rapid assimilation—Nutman, 1937).

Class experiments conducted by the writer early in 1939 to determine the percentage of sucrose in the cane leaf at different hours of the day showed that there was hardly any increase at all between the hours of 11.00 a.m. and 2.00 p.m., suggesting that assimilation must be feeble over the midday period.

The writer has been unable to find any references to the photosynthesis rate of sugar cane other than that of McLean already mentioned, and as it was felt that further data on the normal march of apparent assimilation of the sugar cane under natural conditions (as far as possible) were desirable, the following investigations were carried out.

Dry Weight Increase.

At regular intervals throughout the day fifty punches were taken with a large cork borer from a number of leaves, the punches from any given leaf being from one side only of the midrib. At the end of each interval fifty punches were taken from the other side of the midribs of the same leaves and the dry weights of the two sets of punches (viz. those taken at the beginning of the interval and those taken at the end of the interval) were compared. Since preliminary experiments had shown that there were only minute quantities of reducing sugars and no starch in cane leaves, it was considered that the increase in dry weight was due to the formation of sucrose, and the weight of carbon dioxide fixed was calculated on this basis, and expressed as milligrams CO_2 fixed per hour per square decimetre of leaf surface. The results (Table 1) Fig. 1 (*a*) show a considerable increase in dry weight in the early morning and in the late afternoon, but actually a decrease at midday: here it would appear that photosynthesis is not quite keeping pace with translocation.

In dry weight experiments on cane leaves it is necessary to take the samples from as large a number of leaves as possible, because the leaf which is rolled vertically in the bud, is more developed and heavier on the outer side (McLean) 1920.

TABLE 1.

DRY WEIGHT INCREASE.

50 punches taken (half leaf method). Area of 50 punches = 255.6 sq. cms.

Time.	Increase in Dry Weight in grams.					Mean Increase.	Mgms. CO_2 fixed per sq. dm per hour.
6-8 a.m. ...	.068	.064	.058	.002	.004	.039	11.4
8-10 do. ...	.004	.004	.096	.080	.016	.040	11.7
10-12 noon ...	.000	—.016	.058	—.006	.000	.007	2.0
12-3 p.m. ...	.042	.042	—.006	—.060	—.002	.004	—1.2
3-5 do. ...		.064	.010		.020	.031	9.1

PHOTOSYNTHESIS OF SUGAR CANE.

CO_2 fixation as measured by dry weight increase.

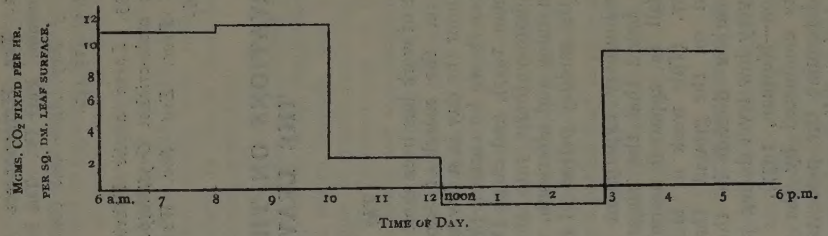

Fig. 1(*a*)

CO_2 uptake.

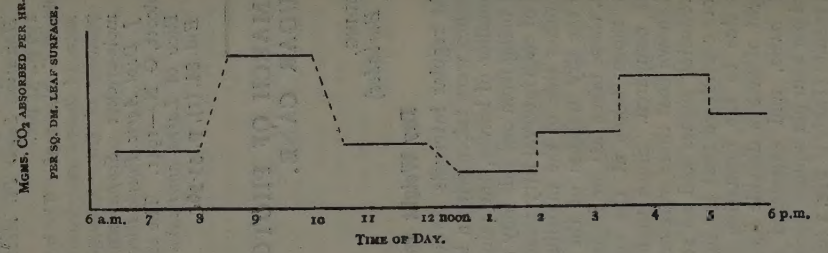

Fig. 1(*b*)

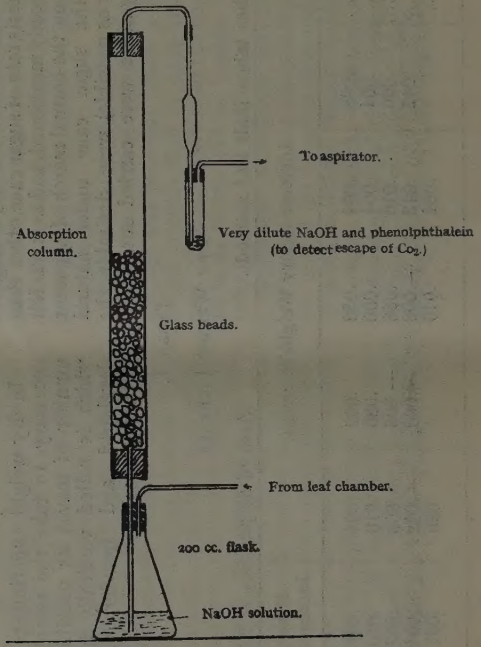

Fig. 2.

TABLE 2.

CARBON DIOXIDE UPTAKE.

Area of leaf = 60 sq. cms. 18 litres of air passed over leaf each 1½ hour period.

Time.	No. of ccs of N/10 HCl = Caustic soda solution in absorption apparatus.								
	1. Air.	2.	3.	4.	5.	6.	7. Mean	8. Mean difference per hour.	9. App. assimilation per sq. dms per hour.
6.30-8 a.m. ...	103.0	102.0	105.0	106.0	105.0	105.0	104.6	1.1	4.03
8.30-10.00 a.m....	104.0	110.0	106.0	111.0	106.5	107.0	108.1	2.73	10.01
10.30-12 noon ...	106.0	108.0	—	109.75	106.5	107.0	107.81	1.206	4.42
12.30-2 p.m. ...	106.0	107.0	106.0	108.25	106.0	107.0	106.85	.566	2.075
2.00-3.30 p.m. ...	106.0	108.0	107.0	110.0	108.0	108.0	108.2	1.37	5.02
3.30-5.00 p.m. ...	106.5	110.5	108.0	110.5	112.0	—	110.25	2.50	9.17
5.00-6.00 p.m. ...	106.5	—	—	106.75	109.0	108.5	108.08	1.58	6.79

Carbon Dioxide Uptake.

The method was similar to that employed by Murray in his work on cacao, and will not be fully described here. A diagram of the apparatus is given. (Fig. 2.) The leaf chamber was a thin walled glass tube, about five inches long by one and a half inches in diameter, and the area of the leaf enclosed was approximately 60 sq. cms. With an air flow of about 12 litres per hour the air was never depleted of more than 25 per cent. of its carbon dioxide. A thermometer in the leaf chamber showed the maximum temperature attained to be 31°C. The experiments were carried out on five sunny days.

Each determination was of 1½ hours duration. A definite volume of air (18 litres) was passed over the leaf and the carbon dioxide remaining in the air was absorbed by 100 ccs. of caustic soda (about N/5) in the absorption column. The absorption column was washed back into the flask with air-free distilled water, the solution was made up to 200 ccs., 50 cc. portions were removed, barium chloride solution was added to these to precipitate carbonates, and they were titrated with N/10 hydrochloric acid, phenolphthalein being used as indicator. The figures in columns 2 to 6 in Table 2 give the volumes of N/10 HCl equivalent to the whole amount of caustic soda remaining in the absorption apparatus.

Since with the apparatus available it was not possible to perform simultaneous control experiments, on four other days (also fine) control experiments were carried out with the apparatus still in the field, but with no leaf in the leaf chamber. The means of the volumes of N/10 HCl equivalent to the residual caustic soda in the absorption apparatus are shown in column 1 of Table 2. Since these controls were not carried out at the same time as the experiments on the leaf it was considered that the sequence of events would best be shown by calculating the apparent assimilation from the differences of the means of the titrations in the two series of experiments. These mean differences (in ccs of N/10 HCl per hour) are shown in column 8, and the mean apparent assimilation in column 9.

The results show (Table 2 (Fig. 1 (*b*)) that until about 10 a.m. there is a rise in apparent assimilation to a mean maximum of about 10 mgms CO_2 /sq.dm./hour, then a sharp drop, reaching a minimum just after midday, and then a second, but lower maximum, and finally a decline late in the afternoon.

Conclusions.

This work shows that, like coconut, coffee, and cacao, sugar cane shows a marked decrease in assimilation rate during the midday period on bright days. The rate of maximum apparent assimilation is quite high—10 to 12 mgms CO_2/hour/sq. dm. leaf surface.

No attempt has yet been made to study the effect of altering the external conditions (*e.g.* by shading, &c.) on the rate of assimilation, but it is hoped to follow up these preliminary observations with more detailed work in the near future.

Acknowledgments.

The writer desires to thank Professor Cheesman of the Imperial College of Tropical Agriculture and Dr. Phillis of the Cotton Research Station, Trinidad, for helpful and friendly advice in the preparation of this paper.

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A CONSERVATIONIST LOOKS AT CONSERVATION FARMING.*

BY

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NEARLY half a century ago, a wise old professor of geology at Harvard University, Nathaniel S. Shaler, posed one of the most disturbing questions an American has ever asked his country. "It is now a question," he wrote in 1896, "whether human culture, which rests upon the soil, can devise and enforce ways of dealing with the earth which will preserve this source of life so that it may support the men of the ages to come." In fewer words, Shaler might have asked, "Is an enduring civilization possible on this continent?"

In general, it may be said that nature is the best soil conservationist we have known, while man is the poorest. Across the centuries, nature gives a covering skin of vegetative matter to the earth which is ideally suited to the soil and climatic conditions of any given locality. In and on the soil she develops a balance of plant and animal life— a cycle of growth, decay and reproduction.

When man breaks this natural balance by clearing away trees, by ploughing up grasslands, by exposing the soil to wind, rain, and sun, the whole character of the land radically changes. The organic matter in the soil oxidizes and gradually disappears. As a result, the soil structure tends to break down and becomes less porous. Water evaporates more rapidly, and more of it runs downhill to swell the streams; soil washes away with the water, fills lakes and streams with silt, and clogs low lands with colloidal material which disturbs natural drainage. In short, the very acts of clearing and cultivation set in motion a whole train of new land and water relationships; the natural balance is replaced by a downward spiral of ever-accelerating run-off and erosion. It is this cycle that Shaler had in mind when he wondered, 44 years ago, whether civilization and soil conservation are compatible.

Earlier in the history of man when population was sparse and requirements were few, nomadic peoples could subsist on the wild products of natural vegetative growth. But some time back in the unrecorded past an unknown genius conceived the idea of clearing the ground surface, planting seeds in the earth, and growing crops of his own choosing. From that day to this, as civilization has developed, man has become steadily more dependent upon the art, the science, and the business that we know as agriculture. To-day civilization without agriculture is unthinkable; yet agriculture has contributed and is contributing powerfully in may countries toward the weakening and destroying of the basic land resource which is civilization's ultimate source of strength and life.

What is the answer? Is civilization on this continent inevitably a self-destroying process? Or can the ingenuity of man devise and enforce ways of solving this deeply disturbing paradox?

Attempts to control erosion in the United States are fully as old as the Nation itself. Washington, Jefferson, and other early leaders, who were farmers as well as statesmen, advocated erosion control and practised it on their own lands. Throughout most of our history, there always have been a few farmers who perceived the dangers of soil washing and took active steps to prevent it. All too often, however, the end result was failure; and until recent years no definite attempt was made to attack the problem on anything like a Nation-wide scale.

In 1933, for the first time in our history, the Federal Government took cognizance of the soil-erosion evil when it organized the Soil Erosion Service in the Department of the Interior. In 1935 it was transferred to the Department of Agriculture, renamed the Soil Conservation Service, and given permanent status. In the seven brief years of its existence, the Service has helped to bring erosion under control on many thousands of farms. Even more important, it has developed and fostered a new concept of conservation farming—a concept that holds real promise of providing an answer to Shaler's monumental question.

At the core of the Service's programme is the idea of cooperation with nature. Realizing that a wholesale retreat to grass and trees would be economic and cultural suicide, the Service has nevertheless contended that we must go part way. We must approach nature's soil conserving efficiency as closely as possible and still provide for the needs of our human population.

This means that cultivation must be confined as far as possible to the level areas and the gentler slopes. It means that steep and erodible lands must go under soil-guarding cover of perennial vegetation. It also means the application of specific framing measures, such as contour cultivation, terracing, strip cropping, and many other devices, as a substitute for the intricate system of checks and balances created by nature under undisturbed conditions.

The farmer cannot change soil types or climate, but he can so manage the soil as to preserve its productivity, moisture-holding capacity, and general usefulness in a large measure of permanency. Conservation farming *does not mean* returning to nature's original vegetative cover on the land; and *it does not mean* merely the introducing of a few isolated conservation

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practices. It *does mean* the coordinating of all available physical and economic information for the farm as a unit and treating every last acre in accordance with its needs and adaptabilities, the type of farming and the resources that are available to the farmer.

If the objective of securing good land use and proper land management is ever attained, it will be because the principles advocated are simple, clear, and easily understood by the farmers and others. What the farmer wants to know is how much of his farm he can safely cultivate and at the same time receive an adequate return in profitable crops; and what practices, measures, and soil amendments he needs to supplement the vegetative growth for good conservation.

Assuming that the ideal of a permanent agriculture is sound, agriculture must become a planned business. Each individual farm must be planned as a business unit for the best long-time production programme together with conservation of farm resources in accordance with the farmer's managerial ability. All sound planning is based on a definite, comprehensive inventory and a broad knowledge of applicable controls.

In planning for erosion control, it is necessary to determine for each field the extent to which erosion has damaged the land by soil removal, the degree and length of the slope, and the capabilities of the soil type itself. No one of these factors in itself, or any other one factor, is sufficient to use as a criterion for readjustment of farming. The fact that Caribou loam is an excellent potato soil, for example, does not give any guarantee that such soil wherever found in its present condition, is capable of producing a high yield of good, marketable potatoes. With the topsoil gone through the effects of erosion, rebuilding is necessary to get even mediocre results, and the topography may have been changed to such an extent that additional use of the land in row crops will eventually cause washing away of the remainder of the soil. Likewise, slope alone, would not be a good indicator of necessary conservation work. A 5 per cent. slope on a shaley soil might not be a serious erosion hazard, but this same degree of slope on a fine sandy soil or on a wind-blown loess, would be an important factor in farming for good erosion control and moisture conservation.

The economic factors, likewise, are fundamental. The farmer should be, and in most cases is, sincerely interested in soil conservation. But at the same time he is in the farming business primarily to obtain an income rather than to conserve soil. If, then, a conservation farming programme unnecessarily reduces his income or adds considerably to labour and inconvenience, he is not likely to become a wholehearted conservation farmer. A planned conservation programme on a farm should take into account both the physical and economic factors which exist on the farm and the abilities of the farmer. The plan must be sound, practical, and understandable, and it must fit into ordinary farming methods. Each farmer, of course, is intensely interested in the welfare and longevity of the life of the country, but he is naturally more personally interested in his immediate present and future. All these facts must be considered in a conservation programme.

Soil and moisture losses are not due to one or even a small number of causes, and no one remedy is a panacea for the ills. In the past the failures of certain mechanical erosion-control practices have taught scientists that no one practice is likely to be sufficient. If we had only to consider the physical control of water movement, or the holding of soil in place, we could develop controls that would be almost entirely effective. But the job is made more difficult and more challenging by the fact that each farm unit represents a business enterprise as well as a piece of land.

Adequate control of erosion is possible, however, if the farmer observes three basic tenets of good land use. First, there are only two groups of soils from the standpoint of use—those which can be safely cultivated, and those which should never be cultivated. Second, when soils which can be safely cultivated are used, they should be utilized in such a manner that satisfactory structure and fertility are maintained and wastage due to erosion is reduced to a minimum. Third, those soils which should never be cultivated should produce a continuous income in a well-managed programme of grass production for hay or grazing; or they should be used for timber production; or to provide food and cover for wild life on the farm. The farmer who recognizes these truths and uses his soils in this way is a conservation farmer.

Assuming that such a system is satisfactory, the lands considered suitable for cultivation present a varied and difficult problem. The types of crops, the crop rotations, the soil amendments, and the supplementary mechanical measures must become a part of ordinary farm procedure. Furthermore, this farming procedure must lend itself to local conditions, and to the economic needs of the farmer.

Proper handling of cultivated land that is not fit for further tillage requires time, patience, and skill on the part of the farmer. As rapidly as possible, the farmer should revegetate these critical areas with a cover that is both erosion-resistant and economically valuable. Once the cover has been established, whether grass, trees, or shrubs, it should be managed with care so as to preserve its vigour and income-producing value.

Attempting to control erosion by the use of a single practice may be a waste of money; in fact, some conservation measures actually may do more harm than good unless fitted into a complete farm conservation plan in relation to other practices and methods of land use. For example, terracing alone, without consideration of land-use capability or crop rotation or disposal

of surplus water, may cause failure of the entire system with consequent loss and damage not only to the terraced land but even to adjoining fields. The introduction of legumes without proper attention to soil amendments may be a waste of money on seed. Merely designating an area of land to be retired from cultivation to pasture does not make it good pasture. Good grazing control, proper plant food, and careful management are all essential. The development of pasture or hay without planning for profitable utilization through livestock may also be an economic loss to the farmer.

The experience of the Soil Conservation Service definitely proves that lasting conservation benefits accrue only when a profitable use is found for each acre on the farm and when supplementary methods and practices become a part of ordinary farm work. The farmer must feel that phases of pasture management, such as controlled grazing, mowing for weed eradication, and fertilization, are as much a part of profitable soil use in pasture as having animals to utilize the grass. If summer and winter cover crops are necessary in orchards and clean-cultivated fields for soil protection and fertility maintenance, the farmer's cropping system must include them at the proper time. If mechanical measures are necessary on certain lands, they must become as much a part of the ordinary methods of farming the soils of those lands as is harvesting the crop. If woodlands already exist on the farm or if they are established as part of the conservation plan, careful management and systematic harvesting of the trees must become almost second nature with the farmer. Not until all erosion-control measures, such as rotation, strip cropping, terracing, use of cover crops, contour cultivation, fertilization, liming, controlled grazing, and woodland management, become a part of the regular farming system *in the proportions that they are needed* does the farmer have a conservation farming programme.

This flexible and many-sided style of attack on the soil erosion problem already has proved its efficiency and value. In hundreds of Soil Conservation Service demonstration areas and in dozens of farmer-organized soil conservation districts, thousands of farms that were formerly going downhill and steadily losing soil have been made safe and secure against the ravages of rain and wind. These farms are now more efficiently organized and operated than ever before; many of them are producing better harvests and better incomes; and nearly all of them are supporting a more satisfactory way of living on the land. No longer can there be any doubt about the feasibility of controlling soil erosion.

During the past 7 years Shaler's question has been affirmatively answered, at least in part. We have already devised "ways of dealing with the earth which will preserve this source of life so that it may support the men of the ages to come." Whether we can effectuate these conservation methods over all our eroding lands, in time to "head off" and eliminate the growing danger at our feet, is a question for the future.

A MANURIAL EXPERIMENT WITH MERKER AND NAPIER GRASSES.

In an article under this title published in the *Malayan Agricultural Journal*, XXIX, No. 8, 1941, the authors* describe experiments with Merker grass, *Pennisetum purpureum* var. *Merkeri*, and Napier grass, *P. purpureum*, Schumach, which were designed to ascertain the response of these two grasses, planted on two different types of soil, to increasing applications of cattle manure and to different intervals of cutting. The results are compared with those obtained for Guinea grass planted previously on the same areas where it was shown that to maintain the crop yields the application of from 10 to 15 tons of cattle manure per acre per annum is essential.

In the present experiments, cattle manure in a well rotted state was applied to the Merker and Napier grasses at rates varying from 5 to 15 tons per acre per annum. With both grasses it was found that yields were almost directly proportional to the quantity of the manure supplied, while there was a distinct tendency for yields to diminish with an increase in age of the stools. This tendency towards diminishing yields was most marked with the 5 ton rate of application of cattle manure. There was, as in the case of Guinea grass, a close correlation between yield and rainfall.

Investigations on the length of interval between cuttings revealed that heavier yields may be obtained from longer cutting intervals. Within the counts of the 6, 8 and 10 week rotations tested, the quality of the fodder was not materially affected by the intervals between harvests, but both Merker and Napier grasses gave greater yields on "light" than on "heavy" soil, and the response to manuring from Napier grass was twice as great as from Merker grass. The results show that these two grasses, and Guinea grass, are all of the same order as regards rate of stocking calculated on a protein content basis.

When the Merker and Napier grasses were compared with Guinea grass it was found that the latter gave better results on soils of medium texture. The former two grasses should preferably be planted on flat land and on a soil which is light in texture. The authors conclude that "assuming the grasses to be cut at six-weekly intervals it would appear unsafe on soils of the type normally encountered in Malaya to estimate for stocking at a rate exceeding 1¼ cows per acre. All manure would have to be returned to the land and none would be available for market gardening."

* C. D. V. Georgi, A. B. Lucy and Gunn Lay Teik.

THE YIELD OF PERENNIAL FODDER GRASSES IN MALAYA AND ITS IMPLICATIONS.

BY

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AN account of experiments in manuring Merker grass and Napier grass at Serdang in Malaya (1), and previous experience on the same farm with Guinea grass, is summarised in this number on page 50. The experiments were obviously very carefully conducted and the results are admirably reported, but these results are distinctly unusual as compared with those obtained from similar experiments in other tropical colonies. The authors' justifiable conclusions from their experiments are of great general interest, and, if they are widely applicable, they have a significant bearing on the prospects for peasant agriculture in the wet tropics.

Briefly the results of this investigation are that the perennial grasses in question, when tested on either the heavier or the lighter types of soil at Serdang, with good cultivation and proper management, and when manured at a rate of from 10 to 15 tons of farmyard manure each year, give average yields of only 9 to 13 tons of green fodder per acre per annum. This means that when these grasses are used as soiling crops cut at intervals of from 8 to 10 weeks, they will yield less than 100 lb. of green herbage per acre per day, containing on the average under 2 lb. of crude protein. On this basis, allowing for seasonal variations in yield, the grasses will provide a maintenance ration for barely two head of adult cattle per acre, and for little more than one adult animal per acre if the green forage has to supply the production ration in addition to maintenance. The authors make the reasonable estimate that even at the higher rate of stocking, the amount of farmyard manure that would become available for return to the land would not exceed 12½ tons per acre per annum. Now this is the rate of manuring that was given to the experimental plots, and is the minimum considered by the authors to be necessary for the maintenance of the yields of green herbage at the levels quoted. Thus a farmer cultivating these grasses as soiling crops would require all his cattle manure to maintain the fertility of his grass fields, and would have no surplus for any other fields on which to grow his food or money crops. In such a locality, therefore, mixed farming in any reasonable sense of the term (2) would hardly be feasible; and the production of food or export crops on the one hand and dairying or other animal husbandry project on the other, will have to develop as entirely separate and independent forms of agricultural industry. Admittedly, this argument is based on the restrictive hypothesis that the farm itself must be the sole source of supply of the rations fed to the stock and of the fertiliser applied to the land; whereas even a peasant farmer attempting mixed farming in the wet tropics would hardly reduce his management system to the complete simplicity of this experiment. For example, he would in all probability buy some concentrated foodstuffs for his stock rations, and he might even arrange to fertilise his cultivated grasses either partly or wholly with a suitable mixture of artificial manures. By such methods he would improve the quality of the cattle dung and increase the head of stock per acre of grassland; and he would then have some quantity of farmyard manure available for other crops. But purchased foodstuffs or fertilizers are relatively expensive, and therefore, in spite of the obvious considerations just mentioned, it may fairly be conceded that the results of the experiment at Serdang must lead to the conclusion that wherever in the wet tropics similar conditions are found, the prospects and opportunities for mixed farming seem limited and discouraging.

This would be really a return to the basic "free-trade" economic theorem, according to which it should be best for populations in the wet tropics to concentrate on the cultivation of plantation crops which cannot be grown in temperate climates, and to import the bulk of their food from areas better suited to the cheap production of wheat, rice, maize or pulse (3). But on social and political grounds, and even perhaps on long term economic considerations, there is everything to be said for the production of as much as is feasible of a country's own food within its own boundaries. And in the wet tropics the growing of food crops will have to be done largely by peasants working their holdings on a system of mixed farming, or some other system, which will make them largely self-contained in regard to the manuring of their crops and the maintenance of the fertility of their soil. For these reasons the establishment and maintenance of a settled and contented peasantry is considered by many to be almost essential for the general prosperity of most tropical colonies. In the wetter of these colonies reasonably high yields from such grasses as those used in the Serdang experiments is a factor likely to be of fundamental importance in the successful development of mixed farming by peasants. Semi-permanent fodder crops giving a steady and economic return of green fodder per acre are indispensable to this class of peasant farmer for the cheap maintenance of his stock, for ensuring a ready supply of organic manure, and, in all probability, for the recuperation of soil that has been temporarily depleted of soil nutrients by intensive cash or food cropping.

The exact value of perennial grass crops for building up soil fertility anywhere in the tropics has still to be determined; but it seems likely that in the wetter tropical areas, subject to erosion and leaching, their importance in this direction may be considerable. If a good leguminous forage crop for such areas, easy to establish and of reasonable persistence in the face of weed competition, could be found, then the problem of fertility maintenance on a system of mixed farming would soon be solved. But although there are still hopes for the future, no perennial or even semi-perennial leguminous fodder has so far been found which is really satisfactory in the wet tropics; and the perennial cultivated grasses therefore automatically assume an increased importance as possible soil recuperative agencies, in addition to their other duties. Their significance in the establishment of a prosperous agricultural community is thus very great: and it therefore seems important to ascertain whether conditions similar to those at Serdang are of common occurrence in the tropics, and whether such low yields as those recorded there must be the inevitable corollary of such conditions.

In the discussion of their results the authors state that "as in the case of Guinea grass, yield figures far below those commonly suggested, viz. 180 to 240 lb. per acre per day (30 to 40 tons per acre per annum) have been recorded." Actually "30 to 40 tons per acre per annum" rather understates the usual yield from these grasses. For example, in Trinidad, in a series of experiments laid down on the farm of the Imperial College of Tropical Agriculture, on a sandy to gravelly loam soil of rather low nutrient status, the yields obtained from suitable species of perennial fodder grass, with good cultivation, reasonable manuring and correct cutting, were as follows (4):—

	Yield of Green Herbage.	
	Tons per acre per annum	Lb. per acre per day
Elephant grass (*Pennisetum purpureum*)	63.06	387
Guatemala grass (*Tripsacum laxum*)	42.40	260
Para grass (*Brachiaria mutica*)	39.93	245

Even better yields are reported from the Hawaiian Agricultural Experiment Station (5):—

Napier grass (*Pennisetum purpureum*)	80.55	494
Merker grass (*Pennisetum purpureum* var. *Merkeri*)	71.00	436

Experiments with Elephant grass (6) in Ceylon gave yields of the same order, namely 58.8 tons per acre per year on a 6 weeks' cutting rotation and 65.20 tons per acre on an 8 weeks' rotation. Reports from yet other tropical colonies (7, 8, 9), also show that in general the yields of perennial tropical fodder grasses are of a much higher order than any so far obtained at Serdang. When it is considered that a single cut from a forage crop of maize can yield over 19 tons of green fodder (9), yields of the order of forty or even sixty tons from a perennial fodder grass growing for a large portion of each year are not surprising.

It would appear therefore that in the insular tropics, cultivated perennial fodder grasses of a suitable species properly managed and manured should normally continue to give, over a reasonable period of years, at least two or three times the average yields recorded in the experiments at Serdang. On the assumption that these higher yields are generally feasible in the wet tropics, some three to five head of adult cattle—or equivalent other stock—per acre of cultivated fodder crop could be maintained, and the whole outlook and prospects for settled peasant holdings operated on some system of mixed farming become much better. The failure at Serdang to obtain even fair yields from forage crops of such importance for the development of a livestock industry thus seems to call for a critical investigation, in order to try and determine the factor responsible for the subnormal yields. Meanwhile, in spite of the inadequacy of a purely theoretical discussion, unsupported by an intimate knowledge of the field conditions or by data from a detailed soil survey, the following brief analysis of the factors which might be adversely affecting the yields at Serdang may perhaps be permissible.

That there is something radically wrong with the cultural conditions in the widest sense of the term is clearly indicated by the 30 to 40 per cent. drop in yield in the second year, and by an unusually high mortality in the stools after only two years of growth. In contrast to this, crops in other colonies show that, with good management, the senescence factor should not begin to affect the yield of perennial tropical grasses until after 3 to 10 years according to the species (5, 11). A further indication of some abnormality in the growth of the Elephant grass at Serdang is its unusually high content of dry matter, with a mean value of 19.5 per cent. For 6 to 10 weeks old herbage, this is very high as compared with the mean values around 15 per cent., which have more commonly been recorded in other colonies (4, 5). The dry matter content of the young Elephant grass at Serdang is in fact about the same as that found in Trinidad at the height of the dry season, when the growth of the stools is almost at a standstill and when the colour of the foliage indicates a semi-drought condition.

For good yields, the combined effect of climate, soil, manuring and general system of cultivation and management must produce an environment at least reasonably well adapted to the particular crop species that is being grown. Superficially, in none of these directions, either severally or in combination, is there any obvious radical difference between the conditions at Serdang and those obtaining in the other countries where the same grasses thrive so much better. As to climate, for example, the equable tropical temperatures throughout the year in Malaya, and the high annual rainfall, fairly evenly distributed and with no prolonged dry spell, would make one anticipate higher yields in Malaya than in Trinidad. In general fertility and other characteristics, such as depth and drainage, the Serdang soil would seem to be as favourable to good yields from fodder grasses as the soil on the farm of the Imperial College of Tropical Agriculture, Trinidad. Moreover, the experiments in Malaya included two soil types—a heavier and a lighter one—and it appears improbable that both types would be equally unsuitable for the production of a good forage crop. It is known, however, that the soil at Serdang as a whole tends to be relatively poor in available phosphate and that this is the element most likely to be the factor limiting the growth of crop. This is in contrast to conditions on the Trinidad farm where the limiting factor is generally potash rather than phosphate. In many soils, fodder grasses show a very definite response to dressings of a phosphatic fertiliser (5) and this is true of experimental plots of Guinea grass at Serdang (10), particularly on the heavier soil. But this factor, at best, can only partially explain the low yields, since even with dressings as high as 750 lb. of superphosphate per acre per year the yield of green herbage reached a bare twenty tons (10). Furthermore, it is considered that an annual dressing of 12½ tons of farmyard manure should ensure, on the experimental plots, available phosphate sufficient to guard against yields as low as 30 to 50 per cent. of the average for these species of grass. Indeed, the explanation does not seem to lie in the quantity of fertiliser given to the soil. For the total nutrients supplied to the land at Serdang in the 12½ tons of farmyard manure per year actually exceed the amount in the 6 cwt. dressings of artificials applied to the experimental plots in Trinidad (4), from which over 60 tons of Elephant grass were obtained per acre. The actual figures per acre per annum are as follows:—

Farmyard Manure, Serdang: 112 lb. N; 59 lb. P_2O_5; 70 lb. K_2O.

Artificials, Trinidad: 55 lb. N; 50 lb. P_2O_5; 65 lb. K_2O.

Superficially therefore it would appear that neither in the soil nor the climate nor the amount of fertiliser applied, is there anything radically wrong in the Malayan field conditions. Minor improvements in yield might have been obtained by a rather closer spacing of the stools, by cutting them at a lower level, by a longer cutting rotation (in view of the peculiarly slow growth of the crop) and also by the use of artificial fertilisers with a high proportion of phosphate in preference to poor quality farmyard manure. For it is thought that the full fertilising value of farmyard manure may not be realised in a perennial forage crop. But none of these factors is of sufficient importance to bring up the yields to the level of those commonly obtained elsewhere. The environment in which the crops were grown is therefore apparently abnormal in some other, and not obvious respect, such as the soil structure, the water relationships, the minor plant nutrients or the sunshine records. In consideration of this fact, and knowing how differently various species of fodder grass react to relatively small differences in environment or soil, we suggest that the low yields of forage crops at Serdang may mean that none of the species so far experimented with is really suited to the climate and soil conditions obtaining there. This theory could be tested by the establishment, on observation plots, of a wide range of exotic and indigenous grasses in order to see whether any of them show a marked improvement in the general vigour of their growth when compared with the varieties used in the experiments under discussion.

It is hoped that enough has been said to fulfil the main object of this paper, namely, to suggest that the growth and yield of the perennial fodder grasses so far tried at Serdang, are sub-normal and abnormal; and that for one reason or another, still to be defined, the yield of such perennial grasses there is less than half that which they may confidently be expected to give in a more favourable environment. If this be granted, there should be no risk of stock owners misapplying the results of the experiments at Serdang to conditions wherein much better yields may assuredly be procured.

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SOIL CONSERVATION WORK IN PUERTO RICO.

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IN this note some of the work undertaken by the Soil Conservation Service, of the United States of America, and which the writer saw recently in the island of Puerto Rico will be described. It is perhaps pertinent to remark that in Puerto Rico a complete soil survey has already been made so that soil series are known, together with the texture phase of soils in each series. Thus, the conservation surveyor has some basis on which to work, for the soil maps of Puerto Rico are most comprehensive, and all soil types and phases having similar physical properties have been classified into groups according to their present uses and potentialities.

As there are no frosts and as rains may fall over the greater part of the Island in any month of the year, the use of the land is much more continuous than in areas enjoying a continental type of climate. To this must be added the fact that short but extremely heavy falls of rain are frequent, falls of the order of 8 inches of rain in an hour. These falls may last only a few minutes, but the run off is a high proportion of the total fall, the actual proportion depending on a number of factors. A very important one is the type of crop occupying the land, and another the fact that owing to the density of population a great deal of hillside and heavily sloping land up to 45° is under cultivation.

The Soil Conservation Service had, therefore, to adjust the experience gained on the mainland to suit the special and varied conditions of the Island, and, in order that its recommendations and its actual operations would the better fit in with these conditions, initiated a series of research projects. These projects include an examination, under carefully controlled conditions, of run off and erosion from heavily sloping land at Mayaguez. With this object in view numerous plots under various rotations and systems of crop planting are there being studied.

Indigenous grasses and a number of imported grasses are also being studied as to behaviour on different soils and under differing circumstances. The importance of soil cover by herbage, and the necessity for that herbage to have at least some palatability and use have been recognised. With such a large population (540 souls per square mile) more than the mere soil binding qualities of vegetation had to be considered. Thus a special section for the study of forage, fodder and grasses in the widest sense was established at the Rio Piedras Experiment Station.

Furthermore, since the alignment of crops grown on sloping land is important in arresting erosion and encouraging the take up of rainfall by the soil, field work was directed towards demonstrating correct planting practice and to demonstrating that such practice, whilst arresting erosion, did not depress production from the unit so treated.

At Mayaguez, after careful observations in the field, a large scale demonstration, of a suitable means for the reclaiming to pasture of eroded land has been laid down. After all, Nature, up to a point, demonstrates what plants can do in the direction of not only conserving the soil they live on, but also in arresting, gathering and stabilising soil which is then added to the minimum of soil on which these plants commence to grow. In the demonstration, shallow contour furrows, at vertical intervals varying with the degree of slope, were made and, on the soil and brash thus turned out, Molasses grass, *Melinis minutiflora*, was planted by seeding. Guinea grass, *Panicum maximum*, has also been recommended for this purpose. In due course these grasses grow seed and spread on the land between the furrows.

This same system may be recommended for pastures on hillsides, a series of near contour furrows being made to deal with the run off from the strips of land above each one of the furrows. The Service naturally studied the design and treatment of the drainage channels, into which flow the side ways run off or discharge from terraces, contour furrows and topside interceptor drains. The maintenance of these channels was regarded from the aspect of how much of the maintenance could be natural and how little of it had to be artificial. Here the species of grass used for sodding, and the natural succession of grasses in such depressions required study. A careful examination of the work led to the conclusion that it was not enough to adopt the principles and follow the designs but that the study of the most efficient and cheapest natural local methods of treatment were also needed, not only for the Island, but also for the numberless varying circumstances occurring over smaller or larger stretches of the land in the Island.

From the engineering angle the project is well assisted by the volume of data at the disposal of the Conservation Service. Data on sections and slopes of ditches and drains, and vertical interval records are part of the equipment of the Service, and the capacity of its engineers to take all relevant data regarding the land to be treated, and deal with it comprehensively and as correctly as possible is a product of experience; experience which is being increased each year.

Thus the soil conservation section has some fine visual demonstrations displayed in several parts of the Island of actual terracing. The edges of the terraces being formed are held by

grasses which have proved their value in binding an edge and preventing the escape of silt over the edge, down the slope on to the terrace below. Numbers of grasses have been tested for this purpose. Elephant grass, *Pennisetum purpureum*, is recommended, but for narrow terraces on steep land, its tall growth by creating too much shade is an objection. Non-bunching grasses whose heavy fibrous root systems will stand what is practically a continuous earthing up on the topside and whose stiff stemmy growth simulates the characteristics of a close board fence are naturally the best. The steep bank below the edge which is liable to erode is a problem. Molasses grass has been found the best protection but *Indigofera endecaphylla* may be useful. This work is not by any means complete.

Actual terracing to a level step, with finally a slope back from the edge of the step to the foot of the next step above is regarded as ideal, its cost is far too great to permit of much real terracing being done outright. Contour banking with the object of gradually raising the top of the bank so that ultimately a terraced layout may be formed is far cheaper if not ideal or perhaps so effective. These near contour banks serve to arrest the movement of soil and water directly downhill. All movement is gently sideways, and the grade of this sideways fall is at its highest one per cent. Whilst this is not a non-erodible slope it is contended that by suitable cropping systems erosion is kept to a minimum, whilst the chance of water standing in the crop is much lessened; 1/5th of one per cent. of slope is for all practical purposes a non-erodible slope. Where the length of terrace is short, that is, of the order of 100 yards between drainage channels an almost imperceptible fall is practicable.

In effect, the practice simulates that of strip cropping on the contour, with the deliberate intention of working the land over a series of years into near terraces or actual terraces. When one looks at the area of the horizontal projection of the grass protected terrace edges and the banks beneath, it is readily realised that a considerable proportion of the treated land is removed from tillage, and only by proving the added worth of the protected and tillable land which remains will it really be possible to convince the cultivator that he is gaining by the practice. Hence the large scale and impressive practical layout of large blocks of land in the Island constructed largely by funds provided from the budget of the Conservation Service.

The organisation is now, however, in a position to show what can be done, how it is done, and will assist, in so far as engineering is required, in making a suitable layout. It is to be remarked that whilst individuals on their own small or large farms may themselves adopt these practices it is economical and effective to deal with a block of land which may include the farms of several cultivators following an ideal plan to suit the circumstances of the area. The Soil Conservation Service of the U.S.D.A. has recently (June 1941) published a handbook detailing the problem of soil conservation in Puerto Rico and the Virgin Islands. This area is known as Region 2 and the work was until recently under the able direction of Mr. G. L. Crawford. No doubt when public opinion is more crystallised, when the population realises the very great importance of conservation work to the land of the Island and the land of the individual, then the time will come for the formation of groups to follow a formulated scheme embracing the area in which they live. It may be advisable to give such group endeavours legal sanction.

It is as yet too early to assess how far reaching and important this Service and activity will become, or what lasting effect it will have, but, through the educative medium of the schools, the colleges and the clubs, and the good practical sense of some of the present cultivators it is not too much to expect in the future a widespread development of the practice of soil conservation.

PLASTICS FROM BAGASSE—A LOUISIANA PROJECT.*

In making a plastic substance from bagasse, the operation is designed to get rid of the cellulose fibres and obtain the lignin, which forms a crust on these fibres. This is the exact opposite of the operation designed to make bagasse paper; here the object is to destroy the lignin and obtain the cellulose. For destroying the lignin in paper-making, use is made of caustic soda or chlorine. On the other hand, when the lignin is wanted, as it is in this case, the cellulose is destroyed by a reagent which leaves the lignin intact, or in a suitable combined form. The bagasse is first prepared by drying it until it contains about 7 per cent. of moisture. It is then passed through a coarse shredder and filled into an autoclave or digester, where it can be heated under pressure with chemicals. In the course of the investigations that led up to the process, various chemical reagents were tested, and among these it has appeared that the best of them is aniline, a coal-tar product. For making 200 pounds of finished moulding powder, a digester charge would consist of 190 pounds of bagasse and 53½ pounds of aniline. The digester is then sealed, high pressure steam (at over 100 pounds per square inch) is turned into the digester-jacket, and the heating is continued for several hours; in the meantime, the digester contents are continually stirred with a mechanical agitator.

After a sufficient period of heating under pressure, the digester is blown down as rapidly as possible without losing any fine material. The mixture of liquid and a very black solid is

*Article by Dr. O. W. Wilcox, reprinted from *The South African Sugar Journal*, November, 1941, pp. 583-58.

filtered on a vacuum filter; the insoluble material is thoroughly washed with hot water and dried at a temperature of 220°F. It is then ground to powder. This black powder is the base for a plastic material. It is not yet a plastic in itself, but must be put into a condition such that it will flow when pressed in a mould. In other words, it must be plasticized. Various substances may be used as plasticizers. The most suitable appear to be furfural (which itself can be made by hydrolyzing bagasse pith), or various mixtures of furfural, aniline, and phenol. The process as above outlined can be used by anyone without paying patent royalties, but various steps have been patented or are being kept secret until patents can be obtained. These particular steps relate to the precise kind of plasticizer to be used with a product that has been digested in a certain way.

The next step is the use of this lignin-aniline product for making moulded articles. This material is "thermoplastic"; that is, if heated to a sufficiently high temperature under a sufficiently great pressure, it will take the form of whatever mould it is in. This temperature begins at 200°F. and is raised to 360°F. for 7 minutes. The pressure may be as high as 3,500 pounds per square inch. According to reports published by the experts who worked out the process, the properties of the moulded articles may be varied almost at will. For maximum strength, the water-to-bagasse ratio should be high, and low for maximum flow and water resistance. The reverse is true for digestion pressures. A short digestion time will give greater strength, but too short a time is not good. Grinding the powder too fine is also not good. In these and other details the manufacture of plastics from bagasse is already an art.

Besides the aniline process for destroying the cellulose and obtaining the lignin, there is an acid hydrolysis process. In this process the dry bagasse is cooked under pressure with sulphuric acid. Here again a solid residue is obtained, which when ground, dried, and plasticized with aniline becomes a plastic material. This product is also dense, black, opaque, and lustrous, and can readily be machined with high-speed cutting tools or carborundum wheels. Being uniform in physical structure, the moulded products may be ground, sanded and polished throughout their entire body. The relative raw materials costs of these two processes are shown in the accompanying table.

The zinc stearate used in these formulas is for lubricating the mass during the moulding process. It will be noted that the plastic product from the acid process costs a little less than half as much a pound as the product of the aniline digestion. However, the plastic compositions prepared from the aniline-hydrolyzed bagasse exhibit, in general, greater plastic flow, flexual strength, and resistance to moisture absorption than products prepared by acid hydrolysis. These characteristics make the product of the aniline hydrolysis more desirable, especially for use in the electrical equipment industry, where low moisture absorption is especially important. As the matter becomes further developed it may be that the cheaper acid method can be used for articles where strength and moisture resistance are not so important.

RAW MATERIALS COST OF BAGASSE MOULDING POWDERS.

(Based on 1 ton of finished moulding powder.)

Raw Materials.	Acid Process		Aniline Process	
	Quantity *Lb.*	Cost $	Quantity *Lb.*	Cost $
Bagasse, dry ...	2,630	10.52	1,900	7.60
Sulphuric acid ...	27	0.22	...	...
Aniline ...	135	20.25	535	80.25
Furfural ...	135	13.50	135	13.50
Zinc stearate ...	17	5.95	17	5.95
Total cost ...		50.44		107.30
Cost per lb. ...		0.025		0.054

However, the acid method gives one by-product that may be found of interest when and if the bagasse plastics industry assumes large proportions. The acid is used in this process for getting rid of the cellulose, but leaves the lignin. The cellulose is thereby converted into soluble sugars (glucose) which can be washed out of the mass by water. This sugar solution may be boiled down to obtain a stock feed, or it may be fermented with yeast to produce industrial alcohol. If this by-product is recovered it might do something to lower the cost of the main product. Another economy might be found by shaking out the bagasse pith (which has little lignin content) and hydrolyzing it to obtain furfural, which is very useful as a plasticizer for the moulding powder. According to investigations published by the Government Sugar Experiment Station in Formosa, bagasse pith with 12 per cent. of moisture will yield 12 per cent. of its weight of furfural.

It will be noted that the bagasse plastic is in all cases intensely black in colour. It therefore does not lend itself to the fabrication of fancy, transparent, or gaily-coloured toilet articles, although by mixing in various pigments a mottled effect may be produced. The new plastic already seems to have an assured future in the automobile and electrical industries, and it may expand largely in other lines. How much bagasse tonnage it will absorb remains to be seen. It may be that its biggest outlet will be in the form of lustrous and strong sheets than can be employed in cabinet work, floor tiling, &c. Perhaps it may come to compete with the soy-bean plastic which is being considered for moulded automobile bodies and aeroplane fuselages.

CLIMATE AND THE SUGAR CANE.*

Of the dry matter of the plant, the overwhelming part is derived from the air and the residuum only from the soil and it is, therefore, somewhat surprising, when one comes to think of it, that a disproportionate effort is expended on the effects of different soil conditions, particularly in the matter of available plant food. This appears to be due to the emphasis laid on the crop cycle and yields as determined by variables imposed within the single season. Yet climatic variations of no mean order occur from year to year and produce reactions on the plant which may be out of all proportion to those resulting from soil differences. It is of interest, therefore, to try and trace both those reactions to climate and the *modus operandi* of the factors at work. In many cases, particularly in continental tracts, this involves observation over a series of years and a good deal of luck, for it may be several years before sufficiently contrasting seasons are met with. The case is different in the Island cane growing areas, especially those with a mountainous topography, for very different climatic conditions may often be found at very short distances. The Hawaiian islands are peculiarly well situated in this respect; advantage has been taken of this fact by H. F. Clements and his conclusions are given in a paper entitled "Integration of Climatic and Physiologic Factors with Reference to the Production of Sugar Cane."(1)

The work described refers to cane at Waipio and Kailua, both situated on Oahu and only a few miles from each other. At the former place the rainfall is so scant that irrigation is practised, some 100 in. of water being supplied per annum, while the days are very bright and warm; at the latter the rainfall is adequate with an apparently cooler day. Actually there is little difference in temperature, the real difference being in light intensity. The yields obtained from quarter acre plots of the variety 31-1389 at the two stations showed a very large difference; 134 tons cane per acre with quality ratio 7.2 and sucrose per acre 18.6 tons at Waipio, and 65 tons cane per acre with quality ratio 9.0 and sucrose per acre 7.2 tons per acre at Kailua.

The first step in tracing the cause for this large difference is to evaluate the soil effect and, for this purpose, pot cultures in soil from the two stations were grown under Waipio conditions. After four months the small and insignificant difference in growth was, if anything, in favour of the Kailua soil. In the field the only difference in fertilizer lay in the nitrogen application, 225 lbs. N at Waipio and 150 lbs. at Kailua. Relative to plant growth, the application at Kailua is the heavier while leaf analyses indicated that the nitrogen level in the plant was higher at this station than at Waipio.

(1) Hawaiian Planters' Record, Vol. 44 (1940). p. 201.

Since soil differences were inadequate to explain the large divergence in yield, the causes had to be sought elsewhere. The major climatic difference lay, as has been said, in moisture and light intensity. Moisture was largely eliminated by irrigation and could hardly have a controlling effect, and this left light intensity, a measure for which remained to be found. A measure partially indicating this is the "day degrees" devised by DAS who used this measure and found a close correlation between the accumulated "day degrees" and crop yield. The "day degree," being the number of degrees excess of the maximum reading for the day above 70°F., is clearly not a full measure of the light intensity for, in cloudy weather, the temperature curve is very irregular. Actually the accumulated day-by-day totals of "day degrees" at Waipio and Kailua respectively were 9374 and 5693. This is clearly not a full measure of the yield difference for, with 134 tons, at the former station, the latter station should have yielded some 81 tons. Another measure had to be found and it was found in what are termed "sunlight degrees." This measure is based on thermograph readings of a white bulb within a standard weather kiosk and of a black bulb exposed outside. In both cases planimeter measurements are then taken of the area above 50°F. for the daily period, 6 a.m. and 6 p.m., and these are divided by the area of 1°F. for a 12-hour period and the dividend added to the 50°F. base. The difference between the values so calculated for the two bulbs is taken as a measure of light intensity, and cumulative values, as in the case of "day degrees", can be used. In cloudy weather the maximum reading necessarily exaggerates the evaluation of the "day degrees" reading leading to a high ratio between "day degrees" and "sunlight degrees".

Having determined the method of measuring the light intensity, it remained to find a measure of growth. The various possibilities considered cannot be given in detail here; ultimately final selection fell on three factors, length increase of the stem measured monthly—a measure which was found to be in close agreement with the measure based on green and dry weights—leaf area calculated from area of the individual leaf multiplied by number of leaves, and density measured as number of stalks per linear foot of row. This last was only taken into consideration after the sixth month when the crop had closed in.

In a comparison of the leaf areas at the two stations, that for Waipio showed a gradual increase up to a maximum of 11,049 ccm. per plant at 11 months and an equally gradual fall subsequently to 4778 ccm. at 21 months. At Kailua there is no such regularity, the figure reaching a maximum of 7557 ccm. at nine months and remaining substantially constant till the 16th month when a more gradual fall takes place

* Article by H. M. Leake reproduced from *International Sugar Journal*, Vol. 43, p. 234-235.

with the result that, at 21 months, the figure for Kailua is 5426 ccm. against 4778 ccm. for Waipio. The relative density at the two stations remains at unity for the first six months when a gradual fall takes place till, at some 12 months, that of Kailua becomes stabilized at approximately 0.80 of the Waipio figure.

An attempt is now made to calculate the growth increment for Kailua from the Waipio figures using the above factors. The formula adopted is

$$G_k = \frac{G_w \times A \times L}{D}$$

where G_k and G_w are the growth increments at Kailua and Waipio respectively, A is the ratio of leaf areas at these two stations, L the corresponding ratio of light intensities and D the corresponding ratio of the densities. The figures for G_w and G_k are both tabulated and plotted and the agreement of the calculated with the found values is very close indeed, though the coefficient of co-relation is not given. Other climatic factors necessarily enter into general consideration of climate and plant relationships, temperature, particularly in its seasonal range, and length of daylight. In these particulars, however, the climate of Hawaii is very uniform leaving the intensity of sunlight as the dominant factor.

Though sunlight is shown, thus, to be the dominating factor, it does not follow that the fertilizer requirements are unimportant. Within the limit set by this uncontrollable natural condition of growth, fertilizers can, and do have a material effect if the three plant-food elements tend to act as limiting factors. The economic aspect here comes into prominence. Estimates of fertilizer requirements based on field experiments are valid only for the particular area and particular season and to apply fertilizers based on trials at Waipio, for instance, to the crop at Kailua would entail waste for, with the lower limit of growth at the latter place, the requirement would be smaller. What is desired, therefore, is some ready method by which the plant can be followed throughout its growth in the actual field. This desirability applies particularly to nitrogen which is held in the soil in a relatively unstable condition. The aim is to find an index of the plant's general state of well-being indicating its reaction to the weather.

This part of the investigation consisted of comparisons of the composition of corresponding parts of the plant at the two stations at monthly intervals. Subdivision of the plant was very detailed; stem from base in sections of three internodes; leaves No. 7 from top to lowest divided into blades and sheaths and the corresponding stalk section, leaves 3 to 6 similarly divided, with stalk; leaves 1 and 2, with the meristematic tissue, divided into two, a lower 5 in. and the remainder. Details of potash and phosphorus content are given only for leaves 3 to 6 which, being the most active part of the plant, are likely to give the best index.

With regard to phosphorus, the level at Waipio at an average of 0.301 per cent. dry weight is higher than at Kailua at 0.245 per cent. but various cogent reasons are given for believing that this lower value is no indication of deficiency; at Waipio this element appears to be in excess. With regard to potash the relative figures are 1.54 and 1.89 per cent. of dry weight and again; evidence is produced to justify the belief that, in both cases, potash is being taken up in excess of requirements.

The nitrogen analysis is much more intricate owing to the differential distribution within the plant and is given in detail. The meristem is richest (over 2.5 per cent. dry weight) followed by the elongating blades and stalk (over 1.0 per cent.) Comparatively there is little difference in any part of the green portion but below, at Waipio, the nitrogen content falls from 0.26 per cent. in the top internodes to 0.14 per cent. in the lowest while at Kailua the content remains practically constant at between 0.51 and 0.36 per cent. From consideration of the detailed figures it is concluded that the best index for nitrogen is given by the percentage composition (dry weight) of the young leaf blades.

The industry, however, is not concerned only with weight of cane, the sucrose content is of great importance. An equally detailed analysis of the total sugars, corresponding to the nitrogen analysis has been made and given and the total sugar content in the young leaf sheaths is taken as index, which will rise with sub-normal, and fall with super-normal growth. For the first 16 months of the crop season (under the Hawaiian conditions of the actual experiment) it is desired to keep carbohydrate formation and consumption balanced and, from the present record, the above index, is found to be near 10 per cent. After that period it should rise to some 15 per cent. Any considerable rise or fall above this figure indicates some mal-adjustment the cause of which must be sought in the other indices, in the present case sunlight intensity index, nitrogen index and moisture index (dry weight of young leaf sheaths as percentage of green weight), for potash and phosphorus are here adequate throughout growth; but, so long as the total sugar index ranges around 10 per cent., maximum growth under the conditions is being obtained. The major practical control is water supply which indirectly affects nitrogen absorption, a control which is applied during the season of growth. It would seem possible also to adapt the nitrogen supply to the greater or less expected demand.

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CINCHONA CULTIVATION IN THE NETHERLANDS INDIES.*

The two species cultivated in Java to-day are *Cinchona Ledgeriana* and *C. succirubra*, the latter being used chiefly as a stock for *C. Ledgeriana*. Conditions which suit Cinchona best are a tropical hill climate with average daily temperatures from 15° to 25°C. and rainfall about 3,000 mm., fairly evenly distributed over the year, and well-drained virgin soil rich in humus. Old cinchona land can be replanted after two or three years' rest, during which period it should carry leguminous crops. If grafted plants are used soil exhaustion is diminished. Propagation is by seeds, grafts and cuttings, the latter being seldom used. Very careful selection and re-selection is carried out with the plants supplying the grafts, the characters required being at least 10 per cent. quinine content, a quick and good habit of growth and resistance to pests and diseases. The seeds are raised in walled and covered frame sheds, an aperture for light covered with oiled linen being left along both sides of the ridge pole. The seed bed is dry humus earth free from unreduced organic matter; because of the small size of the seeds watering is by spray pump. The secret of success is maintenance of the correct humidity. As the seedlings grow the shed walls are removed gradually and replaced by bamboo trellis. The young plants are thinned, the thinnings being planted elsewhere, still under cover but with more light and in ordinary garden soil. All seedlings are transplanted to outdoor nursery beds within six months from germination. These transplants are still shaded with light roofs of fern which are raised as the plants grow, keeping always 10 cm. above them. Finally these protections are also removed. The seedlings can be grafted in about 18 months. Manuring usually takes the form of green manure supplied by the hedges of *Leucaena glauca* which line the terraces. Farmyard and sulphate of ammonia and seed meal of *Leucaena* and kapok are also given. Pruning is aimed at keeping an unbranched single stem to two-thirds of the height in the older trees and one-third of the height in the younger. Pests and diseases are not numerous. The first yields are obtained from the prunings and later from the thinning and removal of too closely planted trees. Prunings and thinning are never carried out to increase yield. When the yield from these sources begin to decline is the most economical time to cut the whole plantation. In harvesting, the tree is felled and the bark removed from every part of the tree thicker than a lead pencil, including the roots. The bark is beaten with a wooden mallet to facilitate removal. Drying is usually in ovens at temperatures of 60°C. and later 80°C. The three grades of bark are known as pipes, ribs and chips. Pipes are the longest pieces, usually curled (with assistance) through drying into tubular form. Ribs are badly removed sections about 25 cm. by 1 cm. They are bundled in 25s, the binding being tightened during drying to keep them flat. Chips are produced by scratching off the bark of otherwise unsuitable sections. The roots produce only chips. The bark is dealt with by eighteen factories.

* From *Horticultural Abstracts*, Vol. XI, p. 55.

EFFECT OF FOREST LITTER ON SOIL TEMPERATURE.

Oak groves, principally Arizona white oak, *Quercus arizonica*, and Emory oak, *Q. emoryi*, are common in places throughout the chaparral vegetation of southwestern watersheds. Such tree groves in natural conditions have typical hardwood forest ground cover or litter, whereas in the surrounding chaparral, grasses are a very important part of the soil cover and a primary influence in holding shrub litter in place.

Studies conducted by the Southwestern Forest and Range Experiment Station on the Sierra Ancha Experimental Forest watershed, located in central Arizona above Roosevelt Dam, indicate the insulating effect of litter in both the oak groves and chaparral. Here soil temperatures at a depth of 3 inches were compared under different cover conditions—(1) where litter accumulates and is held in place by herbs and (2) where litter washes away leaving the ground bare.

The results of thermograph records during a period of 8 weeks in October and November 1938 are considered typical. For this period, the average daily minimum temperature was 44°F. for bare soils as compared to 49°F. for litter-covered soils. These temperatures substantiate the common observation that bare ground will freeze harder and deeper than ground covered by litter. Furthermore, in many instances the litter-covered ground remains unfrozen when bare ground freezes. Such conditions affect infiltration of rain and snow water, ground and surface-run off, and also the natural processes of re-vegetation.

The hourly records also show the lag of several hours between air and soil temperature changes. The minimum air temperature usually occurred between 6 and 7 a.m., whereas the minimum soil temperature was usually recorded between 10 and 11 a.m.

As regards re-vegetation, the average daily maximum temperatures recorded were 62°F. for bare soils and 55°F. for soils with litter. Accordingly, the daily range in temperature for bare soils amounted to about 18°F. as compared with 6°F. for litter-covered soils. The conditions for germination, vegetative reproduction, and survival of new plants, particularly during stress periods, should be much more favourable in litter-covered soils because of the insulating effect of litter on both soil moisture and temperature.—(*Chronica Botanica*, VI, p. 440.)

CHEMICAL NOTES.

(Compiled by the College Department of Chemistry and Soil Science.)

Use of Exchange Synthetic Resins in Water Softening.

During the course of experiments which were made in 1934 as part of the programme of the Water Pollution Research Board, it was discovered that resins prepared from certain polyhydric phenols and tannins possess marked base-exchange properties, and that resins prepared from certain aromatic bases possess acid-exchange properties. These resins are not destroyed by the action of dilute solutions of acids, such as sulphuric and hydrochloric acids, and of alkalies, such as caustic soda and sodium carbonate. Several of the resins are now in commercial use in various parts of the world for softening water, for removal of salts to produce the equivalent of distilled water, and for the recovery of valuable materials from waste waters. The exchange values of some of the base-exchange resins is a little greater than that of synthetic aluminosilicates. These resins, after regeneration with a solution of sodium chloride, can be used to replace the calcium and magnesium by hydrogen in the same way as for the carbonaceous base-exchange materials.

The acid-exchange resins are unique in that no other group of substances with similar acid-exchange properties has been discovered. Expressed in terms of chemical equivalents, the exchange value of the best of the acid-exchange resins is about twice as great as that of the base-exchange resins. This means, for example, that if one volume of the base-exchange resin, previously treated with acid, is required to remove the calcium, magnesium, or sodium from a given volume of a solution of the sulphates of these metals, only 0.5 volume of the acid-exchange resin is required to take up the sulphuric acid in the water treated by the base-exchange resin.

By utilizing a base-exchange resin or a carbonaceous base-exchange material and then an acid-exchange resin, natural waters containing dissolved salts can be converted into water containing little or no dissolved solids. If the original solution includes bicarbonates, then the treated water may be saturated with carbon dioxide, which should generally be removed by subsequent treatment.—(*Chemistry & Industry*, Vol. LX, p. 798.)

* * *

Microbiological Approach to Vitamin Production.

Tartaric acid may be produced commercially by a process starting with fermentation of glucose or gluconic acid by *Acetobacter* to give a 90 per cent. yield of 6-ketogluconic acid in thirty-five hours, suggested Dr. R. D. Coghill, of the Northern Regional Research Laboratory, Peoria, at a meeting of the American Chemical Society. This substance is oxidised in air with proper catalysts directly to d-tartaric acid.

Dr. Coghill held out the hope that other moulds, yeast and bacteria, might be developed to produce large amounts of vitamin materials, such as biotins, pantothenic acid, nicotinic acid, and even sterols convertible to vitamin D.—(*Manufacturing Chemist*, Vol. XII, 1941, p. 187.)

* * *

Substitute for Linseed Oil.

Seed of *Hyptis spicigera* Lam., from equatorial Sudan and Nigeria, has been investigated by the Imperial Institute and reported to have possibilities as a substitute for linseed and other drying oils. —(*Bull. Imp. Inst.*, 1941, 39, 2, p. 97.)

Constants of oil from the Nigerian seed fall mostly within the limits laid down in the British Standard Specification for raw linseed oil, while the Sudan seed resembles linseed oil still more closely. Oil content of the Nigerian seed (20.5 per cent.) is rather low, that of linseed being commonly about 35 per cent., but the yield of the Sudan seed is 29.1 per cent.

Hyptis seed is used locally as a foodstuff, but Dr. J. D. Tothill, Director of Agriculture and Forests, Sudan, writes that the possibility of its export as a paint oil will be considered after samples of the oil have been obtained from an oil press which is being installed.

Constants of the two oils, compared with B.S.S. No. 632 (1935) for linseed oil, are shown in Table 1.—(*Manufacturing Chemist*, Vol. XII, 1941 p. 187.)

Table 1.

	Nigerian Sample.	Sudan Sample.	Linseed Oil.
Specific gravity at 15/15°C	0.9346	0.9318	0.931 to 0.936
Refractive index at 20°C	1.4835	1.4829	1.4800 to 1.4835
Acid value	6.8	0.9	Not more than 4
Saponification value	191.8	193.1	Not more than 188
Iodine value, Wijs, 1 hour	205.8 %	202.0%	Not less than 175
Unsaponifiable matter	1.59%	1.34%	Not more than 1.5%